

CLAIMS

1 1. A photonic device, comprising:
2 a silicon semiconductor based superlattice that includes a plurality of layers that form a
3 plurality of repeating units, wherein at least one of the layers in the repeating unit is an optically
4 active layer with at least one species of rare earth ion and at least two units in a repeating unit
5 have different thicknesses.

1 2. The device of claim 1, wherein each layer in the plurality of layers is a pure
2 crystalline structure.

1 3. The device of claim 1, wherein the rare earth ion is present with a density of at
2 least 10^{18} ions per cubic cm.

1 4. The device of claim 1, further comprising:
2 one or more cladding layers coupled to the superlattice configured to guide and propagate
3 an optical mode that overlaps at least a portion of the superlattice.

1 5. The device of claim 1, further comprising:
2 first and second electrodes , wherein at least a portion of the superlattice is positioned
3 between the first and second electrodes.

1 6. The device of claim 1, further comprising:
2 a least one electrode that extends from an exterior of the superlattice to an interior of the
3 superlattice.

1 7. The device of claim 1, further comprising:
2 at least one electrically doped p- or n-type layer coupled to the superlattice.

1 8. The device of claim 1, wherein the optically active layer is sandwiched between
2 doped p- or n-type layers.

1 9. The device of claim 1, further comprising:
2 a mode size converter configured to be coupled to an optical fiber and the superlattice.

- 1 10. The device of claim 1, wherein the mode size converter is a tapered waveguide
2 structure.
- 1 11. The device of claim 1, wherein the repeating units are periodic.
- 1 12. The device of claim 1, wherein the repeating units have uniform layer
2 constructions.
- 1 13. The device of claim 1, wherein the superlattice structure is selected to create a
2 global crystal field that interacts with the local crystal field of the constituent host layers to
3 produce a pre-determined optical spectrum of the structure.
- 1 14. The device of claim 1, wherein a crystal field of the device is configured to be
2 spatially variable by altering composition of layers.
- 1 15. The device of claim 1, wherein a composition of the repeating units varies as a
2 function of distance along a superlattice growth.
- 1 16. The device of claim 1, wherein at least one of the layers is amorphous.
- 1 17. The device of claim 1, wherein at least a portion of the active region layer is a
2 narrow band gap semiconductor relative to other layers in a repeating unit.
- 1 18. The device of claim 1, wherein at least a portion of the active region layer is a
2 wide band gap semiconductor relative to other layers in a repeating unit.
- 1 19. The device of claim 1, further comprising at least one spacer layer between two
2 adjacent repeating units.
- 1 20. The device of claim 19, wherein the spacer layer varies in thickness along a
2 growth direction.
- 1 21. The device of claim 1, wherein the repeating units includes ultra-thin layers.
- 1 22. The device of claim 133, wherein the ultra-thin layers have a thickness of 1000 Å
2 or less.

1 23. The device of claim 133, wherein the ultra- layers are thin enough to be non-bulk
2 material layers.

1 24. The device of claim 1, wherein each repeating unit has two or more layers.

1 25. The device of claim 1, wherein each repeating unit is repeated N times, where N
2 is a whole or partial integer of monolayers.

1 26. The device of claim 1, wherein each repeating unit has at least two layers made
2 with different compositions.

1 27. The device of claim 1, wherein each repeating unit has at least two layers with
2 different thicknesses.

1 28. The device of claim 1, wherein each repeating unit has three layers made of with
2 different compositions.

1 29. The device of claim 1, wherein each repeating unit has a silicon oxide layer.

1 30. The device of claim 1, wherein each repeating unit has an oxygen-doped silicon
2 layer.

1 31. The device of claim 1, wherein each repeating unit includes an electrically doped
2 p- or n-type layer.

1 32. The device of claim 1, further comprising:
2 at least one crystal growth modifier M included in at least one crystalline layer of each
3 repeating unit in the form of SiM_x , where x is less than 1.

1 33. The device of claim 32, wherein the growth modifier M is a crystalline compound
2 comprising a rare-earth R and M is at least one of C, H, O, N, P, As, B, Sb, Co, Ni, Ir, Sn and Pb
3 in the form R_xM_y .

1 34. The device of claim 1, wherein the rare earth ion is selected from at least one of
2 Er, Pr, Nd, Eu, Ho, Pm, Tb, Sm, Tm and Yb.

- 1 35. The device of claim 1, wherein the rare earth ion is Er.
- 1 36. The device of claim 1, wherein the multi-layer silicon based superlattice is
2 positioned on a silicon substrate.
- 1 37. The device of claim 1, wherein the multi-layer silicon based superlattice is grown
2 on a silicon substrate.
- 1 38. The device of claim 1, wherein the multi-layer silicon based superlattice is grown
2 on an (001)-oriented surface of the silicon substrate.
- 1 39. The device of claim 1, wherein the multi-layer silicon based superlattice is grown
2 on a (111)-oriented surface of the silicon substrate.
- 1 40. The device of claim 1, wherein the multi-layer silicon based superlattice is grown
2 on at least one h, k and l-oriented surface of the silicon substratem wherein h, k, and l are sets of
3 integers that are crystallographic Miller indices notation.
- 1 41. The device of claim 1, wherein the multi-layer silicon based superlattice is grown
2 on one of a geometrically and compositionally patterned silicon substrate.
- 1 42. The device of claim 1, wherein the multi-layer silicon based superlattice is
2 deposited in a superlattice growth direction and has a laterally ordered structure substantially
3 perpendicular to a growth direction.
- 1 43. The device of claim 1, wherein the multi-layer silicon based superlattice is
2 deposited in a superlattice growth direction and has a laterally ordered structure substantially
3 perpendicular to a growth direction.
- 1 44. The device of claim 1, wherein the multi-layer silicon based superlattice is grown
2 on a silicon-on-insulator wafer.
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- 1 45. The device of claim 1, wherein the active region layer has a lattice constant that is
2 less than a lattice constant of an underlying bulk silicon substrate.

1 46. The device of claim 1, wherein the active region layer has a lattice constant that is
2 less than a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is
3 different from a lattice constant of an underlying bulk silicon substrate.

1 47. The device of claim 1, wherein the active region layer has a lattice constant that is
2 equal to a lattice constant of an underlying bulk silicon substrate.

1 48. The device of claim 1, wherein the active region layer has a lattice constant that is
2 equal to a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is
3 different from a lattice constant of an underlying bulk silicon substrate.

1 49. The device of claim 1, wherein the active region layer has a lattice constant that is
2 greater than a lattice constant of an underlying bulk silicon substrate.

1 50. The device of claim 1, wherein the active region layer has a lattice constant that is
2 greater than a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that
3 is different from a lattice constant of an underlying bulk silicon substrate.

1 51. The device of claim 37, wherein at least one layer in a repeating unit has a lattice
2 constant that is sufficiently different from a lattice constant of the substrate to be substantially in
3 a state of elastic mechanical stress.

1 52. The device of claim 37, wherein at least two of layers of repeating units have
2 substantially equal and opposite mechanical strain energy and strain states and each repeating
3 unit is substantially lattice matched to the silicon substrate.

1 53. The device of claim 37, wherein at least two of layers of repeating units have
2 substantially equal and opposite mechanical energy and strain states and each repeating unit is
3 substantially lattice matched to the pseudo-substrate buffer layer.

1 54. The device of claim 14, wherein the crystal field is modified by a strain field
2 induced by lattice mismatched layers in a repeating unit.

1 55. A photonic device, comprising:

2 a silicon semiconductor based superlattice that includes a plurality of layers that form a
3 plurality of repeating units, wherein at least one of the layers in the repeating unit is an optically
4 active layer with at least one species of rare earth ion and at least two units in a repeating unit are
5 made of different compositions.

1 56. The device of claim 55, wherein each layer in the plurality of layers is a pure
2 crystalline structure.

1 57. The device of claim 55, wherein the rare earth ion is present with a density of at
2 least 10^{18} ions per cubic cm.

1 58. The device of claim 55, further comprising:
2 one or more cladding layers coupled to the superlattice configured to guide and propagate
3 an optical mode that overlaps at least a portion of the superlattice.

1 59. The device of claim 55, further comprising:
2 first and second electrodes, wherein at least a portion of the superlattice is positioned
3 between the first and second electrodes.

1 60. The device of claim 55, further comprising:
2 a least one electrode that extends from an exterior of the superlattice to an interior of the
3 superlattice.

1 61. The device of claim 55, further comprising:
2 at least one electrically doped p- or n-type layer coupled to the superlattice.

1 62. The device of claim 55, wherein the optically active layer is sandwiched between
2 doped p- or n-type layers.

1 63. The device of claim 55, further comprising:
2 a mode size converter configured to be coupled to an optical fiber and the superlattice.

1 64. The device of claim 55, wherein the mode size converter is a tapered waveguide
2 structure.

- 1 65. The device of claim 55, wherein the repeating units are periodic.
- 1 66. The device of claim 55, wherein the repeating units have uniform layer
2 constructions.
- 1 67. The device of claim 55, wherein the superlattice structure is selected to create a
2 global crystal field that interacts with the local crystal field of the constituent host layers to
3 produce a pre-determined optical spectrum of the structure.
- 1 68. The device of claim 55, wherein a crystal field of the device is configured to be
2 spatially variable by altering composition of layers.
- 1 69. The device of claim 55, wherein a composition of the repeating units varies as a
2 function of distance along a superlattice growth.
- 1 70. The device of claim 55, wherein at least one of the layers is amorphous.
- 1 71. The device of claim 55, wherein at least a portion of the active region layer is a
2 narrow band gap semiconductor relative to other layers in a repeating unit.
- 1 72. The device of claim 55, wherein at least a portion of the active region layer is a
2 wide band gap semiconductor relative to other layers in a repeating unit.
- 1 73. The device of claim 55, further comprising at least one spacer layer between two
2 adjacent repeating units.
- 1 74. The device of claim 73, wherein the spacer layer varies in thickness along a
2 growth direction.
- 1 75. The device of claim 55, wherein the repeating units includes ultra-thin layers.
- 1 76. The device of claim 75, wherein the ultra-thin layers have a thickness of 1000 Å
2 or less.
- 1 77. The device of claim 75, wherein the ultra- layers are thin enough to be non-bulk
2 material layers.

- 1 78. The device of claim 55, wherein each repeating unit has two or more layers.
- 1 79. The device of claim 55, wherein each repeating unit is repeated N times, where N
2 is a whole or partial integer of monolayers.
- 1 80. The device of claim 55, wherein each repeating unit has at least two layers made
2 with different compositions.
- 1 81. The device of claim 55, wherein each repeating unit has at least two layers with
2 different thicknesses.
- 1 82. The device of claim 55, wherein each repeating unit has three layers made of with
2 different compositions.
- 1 83. The device of claim 55, wherein each repeating unit has a silicon oxide layer.
- 1 84. The device of claim 55, wherein each repeating unit has an oxygen-doped silicon
2 layer.
- 1 85. The device of claim 55, wherein each repeating unit includes an electrically doped
2 p- or n-type layer.
- 1 86. The device of claim 55, further comprising:
2 at least one crystal growth modifier M included in at least one crystalline layer of each
3 repeating unit in the form of SiM_x , where x is less than 1.
- 1 87. The device of claim 85, wherein the growth modifier M is a crystalline compound
2 comprising a rare-earth R and M is at least one of C, H, O, N, P, As, B, Sb, Co, Ni, Ir, Sn and Pb
3 in the form R_xM_y .
- 1 88. The device of claim 55, wherein the rare earth ion is selected from at least one of
2 Er, Pr, Nd, Eu, Ho, Pm, Tb, Sm, Tm and Yb.
- 1 89. The device of claim 55, wherein the rare earth ion is Er.
- 1 90. The device of claim 55, wherein the multi-layer silicon based superlattice is

2 positioned on a silicon substrate.

1 91. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 grown on a silicon substrate.

1 92. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 grown on an (001)-oriented surface of the silicon substrate.

1 93. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 grown on a (111)-oriented surface of the silicon substrate.

1 94. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 grown on at least one h, k and l-oriented surface of the silicon substratem wherein h, k, and l are
3 sets of integers that are crystallographic Miller indices notation.

1 95. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 grown on one of a geometrically and compositionally patterned silicon substrate.

1 96. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 deposited in a superlattice growth direction and has a laterally ordered structure substantially
3 perpendicular to a growth direction.

1 97. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 deposited in a superlattice growth direction and has a laterally ordered structure substantially
3 perpendicular to a growth direction.

1 98. The device of claim 55, wherein the multi-layer silicon based superlattice is
2 grown on a silicon-on-insulator wafer.
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1 99. The device of claim 55, wherein the active region layer has a lattice constant that
2 is less than a lattice constant of an underlying bulk silicon substrate.

1 100. The device of claim 55, wherein the active region layer has a lattice constant that is
2 less than a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is
3 different from a lattice constant of an underlying bulk silicon substrate.

1 101. The device of claim 55, wherein the active region layer has a lattice constant that
2 is equal to a lattice constant of an underlying bulk silicon substrate.

1 102. The device of claim 55, wherein the active region layer has a lattice constant that
2 is equal to a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant that is
3 different from a lattice constant of an underlying bulk silicon substrate.

1 103. The device of claim 55, wherein the active region layer has a lattice constant that
2 is greater than a lattice constant of an underlying bulk silicon substrate.

1 104. The device of claim 55, wherein the active region layer has a lattice constant that
2 is greater than a lattice constant of a on a pseudo-substrate buffer layer with a lattice constant
3 that is different from a lattice constant of an underlying bulk silicon substrate.

1 105. The device of claim 91, wherein at least one layer in a repeating unit has a lattice
2 constant that is sufficiently different from a lattice constant of the substrate to be substantially in
3 a state of elastic mechanical stress.

1 106. The device of claim 91, wherein at least two of layers of repeating units have
2 substantially equal and opposite mechanical strain energy and strain states and each repeating
3 unit is substantially lattice matched to the silicon substrate.

1 107. The device of claim 91, wherein at least two of layers of repeating units have
2 substantially equal and opposite mechanical energy and strain states and each repeating unit is
3 substantially lattice matched to the pseudo-substrate buffer layer.

1 108. The device of claim 91, wherein the crystal field is modified by a strain field
2 induced by lattice mismatched layers in a repeating unit.